Potential Technologies for Managing Livestock Manure

This is a listing of some potential technologies for managing livestock manure above and beyond typical land application. It is not meant to be a complete description or analysis of these technologies, but rather to give an indication of alternatives available for livestock operations in Dane County. No preference is implied by the order in which they are listed. This listing will be updated periodically, and readers are invited to submit comments or additional information.

1. Anaerobic (without oxygen) digestion systems include a variety of approaches, with a multitude of names, including:

- covered lagoon
- plug flow
- complete mix
- temperature phased
- slurry loop
- anaerobic sequencing batch reactor
- fixed film
- thin film
- mobilized film
- attached media
- two-stage digester
- floating bed

Also classified by their operating temperatures (psychrophilic (ambient temperatures), mesophilic (30-40º C, 86-104º F) and thermophilic (120-140º F)), there are already around 20 anaerobic digestion systems processing livestock manure in operation in Wisconsin – mostly plug flow and complete mix systems -- producing methane that is burned to produce electricity and recovering solids for bedding. There is also research on biogas generation using an anaerobic catalysis and/or photocatalysis by Michael E. Zorn of the University of Wisconsin-Green Bay (funded by Focus on Energy). Zorn is attempting to use these processes to help convert dairy manure into biogas. Research has also been funded by Focus on Energy to enhance the decomposition by the use of ultrasound (sonication), along with other research elsewhere.

Anaerobic digestion results in the nearly the same quantity of by-products as was put into the system. It does not change the total of nutrients (N, P, K) from what a lagoon produces, although changes the form of some nutrients and reduces bacterial counts.

2. Aerobic digestion. These systems use oxygen and do not produce methane gas. As with anaerobic systems, several forms are available, including:

- lagoons with air injection
- fixed film
- suspended growth/activated sludge
- aeration

It is not known if any of these systems are in operation in Wisconsin.

3. Incineration – a manure incinerator has been built in Brown County, WI with the goal to also produce electricity. The system started up in late 2005, but has had significant operating problems, and is not currently operational in January 2007. By-product is said to be an ash of 2% of the input. The firm's web page is at http://www.burnmanure.com/ and a description of the system is found on the Internet at http://www.agriview.com/articles/2005/12/08/features/producer01.txt. As of July 2007, the system is undergoing revision of its boiler and the firm hopes to be operational later in the year. At the current time, the firm is not marketing their system, but expects to be doing so in early 2008. In addition, incineration facilities have also been built for handling poultry manure. Poultry manure is very dry, and the systems often burn the material with bedding, which facilitates the combustion of the material. .

4. Pyrolysis – Heat is used to convert material to a solid, a liquid fuel and a gaseous fuel in a low oxygen or oxygen-free environment. An Internet search in May 2007 found no systems in operation. A Swiss report published in February 2007 (http://www.klimainfo.ch/fileadmin/user_upload/photogallery/pdf-Dateien/Greenpeace_Biofuels_Endversion.pdf) said that pyrolysis is in the "second generation" of technologies to produce biofuels from plant material, while a Dutch fact sheet on pyrolysis from manure (http://www.mestverwerken.wur.nl/home/..%5CTechniek%5CPdf%5CVergassingPyrolyse.pdf) classifies it as "under development". The Dutch fact sheets notes that pyrolysis is best suited for poultry manure or the dry parts of cattle and swine manure. Two firms are listed in the Dutch fact sheet as being suppliers of pyrolysis systems.

A pyrolysis system is under development in Cashton, Wisconsin. The developers purchased a pyrolysis firm in Australia and had the prototype shipped to Wisconsin in late 2005. Demonstrated in Green Bay in the first week in May, 2006, no details were provided on materials produced or the economics of the system. The system is now under construction, but an attempt by this compiler in January, 2007 to get more recent data on the composition of the solid char was not successful. A 2006 report on the system and the potential markets for its end products is available on the Internet at http://www.datcp.state.wi.us/mktg/business/marketing/val-add/biobased_industry_grants/pdf/1001Cashton.pdf.

5. Gasification - this is similar to pyrolysis, but the emphasis is on the production of a gaseous fuel. Generally, the gas has a lower energy quantity per volume as compared to pyrolysis. It is not a new technology – gasification of coal was used to produce coal gas before natural gas became widespread, and in WW II and shortly thereafter, some cars in Europe had gasification systems to make a fuel gas out of wood. Thus, gasification can be implemented on a wide range of sizes. A description of the basics of gasification can be found in a Power Point type of presentation titled "Thermal Gasification of Livestock Manure and Crop Biomass" on the Internet at http://www.econ.iastate.edu/outreach/agriculture/programs/2001_Renewable_Energy_Symposium/Smeenk.pdf. The Swiss report referenced in the description of pyrolysis calls gasification a second generation technology, while the Dutch fact sheet classifies gasification as a method of pyrolysis.

6. Ethanol production – ethanol is increasingly being added to gasoline, and is most often made from corn. In an internet search for ethanol product from manure, the only references found were from 2001 for a proposed system by researchers at North Carolina State University (http://www.cals.ncsu.edu/agcomm/magazine/spring01/energet.htm http://mark.asci.ncsu.edu/SwineReports/2001/03manbrett.htm). Because no more recent information was found, it is believed that this system was not developed.

7. Conversion to fuel oil or diesel oil – this is a thermochemical process, with work underway at several places in the US and in Europe. At the research level, the University of Illinois has been developing a process for several years to produce an oil from hog manure in partnership with the Illinois Pork Producers Association. An article on their work is on the web at http://www.engr.uiuc.edu/news/?xId=067608800770. Iowa State University has a project that is using cow manure and corn stalks to produce a bio-fuel oil; the project description that was reviewed did not provide a lot of details and this system may be a type of pyrolysis system (http://www.iastate.edu/~nscentral/news/06/jul/biodrying.shtml).

Using a different type of technology to make a fuel oil from manure processing, Smithfield Foods was experimenting with mixing vegetable oil with methane from an anaerobic digestion system to make a bio-diesel fuel at the Circle Four hog farm in Utah. However, according to an Internet article published in February, 2007, it was shut down in early 2007 due to a determination that the economics weren't favorable (http://news.com.com/Fast-food+fat--future+fuel+for+cars/2100-1008_3-6157412.html?tag=item).

A third type of technology is said to have been developed by Green Power Inc. However, information was not found on their web page http://www.cleanenergyprojects.com/ on the experience and outputs from manure.

8. Solids separation

- gravity separation
- weirs, including weeping walls and geo-textile bags
- mechanical screens and presses
- centrifuging
- ultra filtration
- reverse osmosis
- dissolved air floatation
- evaporation

Several of these systems exist in Wisconsin, but overall, it is only at a small percentage of farms. For example, in Dane County, there is only one mechanical press that is in use. A mechanical screen and sand separator was demonstration in Dane County in early July – for more information, see the write up on sand-manure separation systems.

9. By-product utilization

- composting – an example is the work of Professor. Leslie Cooperband, University of Illinois
- biodrying/drying/evaporation
- acidification, followed by evaporation and solids recovery

- vermicomposting – an example is the research of RT Solutions of Geneseo, NY, on the Internet at http://cris.csrees.usda.gov/cgi-bin/starfinder/0?path=fastlink1.txt&id=anon&pass=&search=R=19391&format=WEBFMT6NT and http://cris.csrees.usda.gov/cgi-bin/starfinder/0?path=fastlink1.txt&id=anon&pass=&search=R=45074&format=WEBFMT6NT
- incorporation into plastic lumber – Roger Rowell of the US Forest Products Laboratory believes that this approach is both technically practical and economical and has developed products with both dairy and swine manure. Work is also being done at Michigan State University and Troika Technologies, Manitowoc, WI
- peat moss substitute – Professors Tim Zauche and Mike Compton at UW-Platteville have developed this material, which has won a state award in early 2006. A paper on this technique is available on the Internet at http://www.jgpress.com/Energy05/Zauche_T.pdf. Also, the firm Organix of Walla Walla, WA has announced that it is building a plant to make a peat moss substitute from dairy manure, with the plant expected to be operational in 2007. The firm's web page is http://www.organix.us/
- particle board feedstock – the US Forest Products Laboratory and faculty from the UW-Platteville have developed particle board and other wood-substitute products from manures. An article on this is on the Internet at http://www.madison.com/wsj/home/biz/index.php?ntid=132436&ntpid=3

10. Phosphorus removal systems

- chemical precipitation
- struvite formation and removal
- hydroxylapatite formation and removal
- enhanced biological phosphorus removal

A separate fact sheet has been written and placed on this web page describing and summarizing these technologies, along with an annotated bibliography of struvite formation and removal as related to phosphorus.

11. Phosphorus inactivation – tying up the phosphorus in the soil

12. Nitrification/denitrification for removal of nitrogen. This process is common in wastewater treatment plants, and, while technically feasible for other wastewater streams, is not known to be in use for manure management.

13. Ammonia stripping

14. "Manure munching microbes" – this system is already being used at a Dane County farm (Wagner) as a means to both facilitate the recycling of liquids in a manure flushing system, as well as for providing odor control and solids removal. The microbes cause a stratification of the manure into an upper layer with few solids and lower levels of nutrients – especially phosphorus – and a lower layer with much higher levels of solids and phosphorus. A web page is at http://proactmicrobial.com/index.htm.

15. Wetlands treatment, including constructed wetlands. The following is part of an abstract of a journal paper describing some research for this use:

> In a 2-yr study monitoring fluxes of particulate and dissolved phosphorus (P) in a small artificial wetland for the treatment of agricultural drainage water in Central Switzerland, water residence time was identified as the main factor controlling P retention in the system. Since most of the annual P load (62% as dissolved reactive phosphorus, DRP) was related to high discharge events, it was not average but minimum water residence time during flood events that determined the wetland's P retention. In agreement with a continuous stirred tank reactor (CSTR) model, our investigations suggest a minimum water residence time of 7 d to retain at least 50% of the bioavailable P. The investigated wetland retained only 2% of the bioavailable P, since the water residence time was shorter than 7 d during 61% of time in both years. Settling of phytoplankton rather than DRP uptake into phytoplankton limited the retention of bioavailable P. The overall retention efficiency of 23% total phosphorus (TP), corresponding to a surface related retention of 1.1 g P m^{-2} yr^{-1}, was due to the efficient trapping of pedogenic particles. (Miriam Reinhardt, René Gächter, Bernhard Wehrli and Beat Müller, **"**Phosphorus Retention in Small Constructed Wetlands Treating Agricultural Drainage Water", *J Environ Qual,* 34:1251-1259, 2005)

16. Algae for the tying up of carbon or phosphorus. The algae can then be harvested for use as a soil amendment, in compost, or to produce energy products. An example is a system being developed in Arizona (http://www.eastvalleytribune.com/story/89616), where the proposed system would produce 2400 acres of algae in closed tubes to produce a feedstock for the production of ethanol, using manure as one of the feedstock. The estimate is that the energy value of the algae would be equal to 115,000 acres of corn.

Algae can be used as a feedstock for renewable energy and other resources. For a summary of its potential use for biodiesel, one source of information is the report *A Look Back at the U.S. Department of Energy's Aquatic Species Program: Biodiesel from Algae. Close Out Report*, NREL/TP-580-24190, National Renewable Energy Laboratory, July 1998, 328 pages, available on the Internet at http://www.nrel.gov/docs/legosti/fy98/24190.pdf. A more recent and local article is in the *Wisconsin State Journal* of July 30, 2007, found on the Internet at http://www.madison.com/wsj/home/local/index.php?ntid=203326&ntpid=1.

17. Ozone treatment – it is said that this will result in the manure being "... sterilized immediately, killing odors and pollutants." One such process is called the Candler Waste Elimination System. Stories on this system from 2001 are on the Internet at both http://www.edie.net/news/news_story.asp?id=4437 and http://www.perc.org/pdf/sept01.pdf (see pages 10-11), while a web page is being developed at http://members.aol.com/candlerprocess/opening.htm. However, no more recent information has been found, so it appears that this process might best be characterized as being in the development phase.

18. Desalination – for removal of salts in areas where salt build up in soils or water is a concern. A California wastewater system is implementing a desalination process as part of their system to handle dairy manure.

19. Electric charge – an Israel technology has been licensed to the US firm ElectroCell Technologies, and is said to both result in the capture of some of the phosphorus, as well as reduce insect populations, nitrates and ammonia.

20. Soldier fly conversion – soldier flies will consume manure, reducing nutrient levels (including phosphorus) and the fly pre-pupae can be harvested for animal feed or other purposes. A description of this process is in the book *Understanding Alternative Technologies for Animal Treatment*, by Janelle Hope Robbins. Other works include;

> "The Black Soldier Fly, *Hermetia Illucens*, As A Manure Management / Resource Recovery Tool" by G. L. Newton, et. al.
> http://www.cals.ncsu.edu/waste_mgt/natlcenter/sanantonio/Newton.pdf
>
> "Black Soldier Fly and Others for Value-Added Manure Management", D. Craig Sheppard
> http://nespal.cpes.peachnet.edu/sustain/ibs_conf.pdf
>
> "Using the Black Soldier Fly to Reduce Manure Accumulation in Dairy Calf Facilities in Comanche County, Texas", by Jeffery K. Tomberlin and Bob Whitney
> http://stephenville.tamu.edu/~jktomberlin/resultdemo/studysummary.pdf

There is also research underway in Spain under the auspices of Europe's LIFE-Environment program, under the project ID of LIFE05 ENV/E/000302 ECODIPTERA. To be completed in late 2008, a description can be found on page 78 of the report on the internet at http://www.senternovem.nl/mmfiles/lifeenvcompilation_05_highres_tcm24-175095.pdf. The research organization's web page can be found at http://www.ecodiptera.info/.

21. Wet air oxidation. According to a web page of the Natural History Museum in London, England (http://www.nhm.ac.uk/research-curation/projects/phosphate-recovery/manure.htm), wet air oxidation has been studied for the recovery of phosphates from pig manure. A Dutch fact sheet describes a test system built in the Netherlands in the 1990's and estimates a cost of 25 to 40 € per metric ton and lists the system as being "under development". http://www.mestverwerken.wur.nl/Home/..%5CTechniek%5CPdf%5CNatteOxidatie.pdf . Three firms are listed in the fact sheet as system suppliers.

22. Pasteurization or sterilization. These processes focus on killing micro-organisms, often as a prelude to the reuse of the manure solids, such as for bedding, sale as pelletized material or other uses. The heat produced during anaerobic digestion and composting provide a level of sterilization.

23. Production of chemicals. In a 2003 report titled *Value-Added Chemicals from Animal Manures,* prepared for the US Department of Energy, (http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14495.pdf), a study was done by Washington State University (WSU) and Pacific Northwest National Laboratory (PNNL) to develop technology for using animal manures as feedstocks to produce value-added products. These products include medium-volume commodity chemicals, such as glycols or diols, and protein-based products, such as chemicals or feed supplements. The research focused on two aspects of this approach, including the analysis and treatment of the feedstock to produce intermediate chemical precursors and the aqueous phase conversion of these intermediates to chemicals and other value-added products.

24. Sand filtration. Sand filtration has long been used in the treatment of drinking water as well as in wastewater treatment. Sand filtration for manure treatment is challenged by the clogging of the sand with the heavy particle loading of the manure, and, as an example of the research that has been done, the article "Solid-liquid separation of swine manure with polymer treatment and sand filtration" in the *Transactions of the American Society of Agricultural Engineers* from 2005 (http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=174712) describes work done to use polymers to remove a larger quantity of solids before the sand filtration system to avoid clogging.

Prepared by
John Reindl, Recycling Manager
Dane County Department of Public Works
November 12, 2007
reindl@co.dane.wi.us